THE U.S. NAVAL OBSERVATORY

STAR

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CAPT Ben Jaramillo Relieves CAPT Larsen as USNO Superintendent

On 28 January 2000, CAPT Bernardino (Ben) J. Jaramillo, USN became the 52nd officer to assume the post of Superintendent, U.S. Naval Observatory. He relieves CAPT Dennis G. Larsen, USN, who served as Superintendent from 5 August, 1997 until the Change of Command.

Captain Jaramillo enlisted in the Navy in August 1966. Upon graduation, he entered the Navy Nuclear Propulsion Program as a Machinist Mate and served as an instructor at the A1W nuclear prototype and onboard USS Enterprise (CVA(N) 65) in 1970.

Captain Jaramillo was accepted into the Navy Enlisted Science and Engineering Program and attended the University of Utah receiving a Bachelor of Science in Meteorology. In March 1975, he received his commission as an Ensign and attended the Submarine Officer Basic Course. In December 1975, he reported onboard USS Darter (SS 576) where he qualified in submarines. Captain Jaramillo then served on USS Thomas Jefferson (SSBN 618 Blue) as assistant weapons officer and on USS George Washington (SSBN 598 Blue) as weapons officer.

During his tour at the Naval Postgraduate School, Captain Jaramillo was designated as a Navy Oceanographer. From January 1984 to August 1988, he served at the Naval Oceanography Command Center, Rota, Spain and then reported onboard the USS Dwight D. Eisenhower (CVN 69) as the ships oceanographer and meteorologist. Onboard USS Dwight D Eisenhower, Captain Jaramillo qualified as Underway Officer of the Deck and Command Duty

Please turn to CAPTAIN JARAMILLO, p. 2

The Captain's Corner

CAPT Ben Jaramillo, Superintendent

First, let me start by saying that I am truly honored to be your Superintendent and I hope to live up to your expectations of me. As I said in my Change of Command speech, I am not here just because of what I had accomplished in the past, but because of all of the wonderful men and women who have guided me, helped me, and coaxed me along the way to ensure I was ready to be your Superintendent. I fully expect to continue learning from all of you and will value your thoughts and suggestions as we go down this road together.

I have had the pleasure of personally meeting with many of you during my short time here. I fully intend to personally meet each and every one of you within the next few weeks. I have asked my staff to arrange departmental meetings where I can meet you, tell you a little about me, where I think we need to be going and listen to your questions. I will probably not be able to answer very many questions yet but I will take in your thoughts and comments and strive to get back to you with an honest answer.

You will probably be seeing me wandering the grounds as if I am lost. I just may be lost but my intent is to get out and see where you work and get to know you better. Please bear with my questions and please be honest in your answers. Together we can continue to make this an outstanding place to work and to showcase this jewel to the many visitors, families and friends who will visit here. Thank you.

In This Issue:

CAPTAIN JARAMILLO, cont'd from p. 1

Officer. Captain Jaramillo reported to the staff of the Oceanographer of the Navy in March 1991. In September 1992, Captain Jaramillo reported to the Undersea Surveillance Branch on the staff of the Submarine Warfare Division, Office of the Chief of Naval Operations and in February 1994 he reported to the staff of the Assistant Secretary of the Navy (Research, Development and Acquisition). In July 1996, Captain Jaramillo reported to the headquarters staff of the National Imagery and Mapping Agency and assumed the duties as Chief, U.S. Southern Command Customer Support Team.

Captain Jaramillo holds a Master's Degree in Oceanography and Meteorology. His personal awards include the Legion of Merit, Meritorious Service Medal (three awards), Navy Commendation Medal, and Navy Achievement Medal (two awards) as well as other unit, campaign and service awards. Captain Jaramillo is married to the former Patricia Applegate of Commerce City, Colorado. They have two sons, Phillip and David.

CAPT Dennis Larsen reads his assignment orders before RADM Richard West (N096) and CAPT Ben Jaramillo at the Change of Command ceremony, 28 January 2000.

USNO Celebrates Start of Millennial Year with a Bang and a Ball

Steven J. Dick, History and Public Affairs

The USNO has sponsored some large events in the past (open houses for Comet Shoemaker-Levy 9's smash into Jupiter, Comets Hyakutake and Hale-Bopp, Astronomy Day, and the NOVA 25th anniversary) but they paled in comparison to the complexity of preparations for the USNO inauguration of the millennial year. Because of its timekeeping responsibilities it was clear from the start that the USNO should take advantage of the heightened public consciousness of this special moment in time, and we did. Spurred by an invitation to participate in the White House Millennium Program, the Superintendent appointed the USNO Millennium Committee, which met more than 20 times beginning in February 1998, with some 50 people attending as the event drew near.

The centerpiece of the celebration was the dropping of the time ball from the roof of the main building near the 12-inch telescope dome. Although everyone is familiar with the New York City ball drop on New Year's Eve, very few realize that this grew out of a practical tradition of time dissemination, initiated in the United States in 1845 at the Naval Observatory, by order of the Secretary of the Navy. The ball was dropped every day except Sunday, precisely at noon, to disseminate time to the citizens of Washington, and to ships on the Potomac to rate their chronometers. It was last dropped in Washington in 1936 on top of the Old Executive Office Building via telegraph signal from the USNO. It was therefore appropriate that the current Secretary of the Navy, Richard Danzig, issued an order to drop the time ball to inaugurate the years 2000 and 2001. (The real millennium begins in 2001 – that's another story!). Thanks go to John Pohlman and the Instrument Shop for constructing, mounting and dropping the ball.

But that was only the beginning! In cooperation with the International Astronomical Union, the USNO coordinated an around-the-world ball drop (and cannon firing) at some 20 sites in 8 countries on 6 continents. Many of the events were coordinated via GPS, tying together the old and new methods of time dissemination, and emphasizing the global reach of GPS, for which the USNO provides the time. The project gained considerable media interest for the sites, many of which were historical time balls that were renovated for the project (as in New Zealand).

But, again, that was only the beginning! A countdown clock was erected at the Main gate (still counting down to the real millennium), a web site was produced thanks to Alan Fey, and George Kaplan

produced a now famous millennium logo. Fireworks were secured from the famous Zambelli Internationale company (thanks to a generous donation by the Navy League of the United States), and the Mexican War unit of the National Park Service fired a time cannon. A VIP reception was planned and held in the newly renovated Building 56 and a large adjacent tent, and the Navy Media Center produced a one hour live TV show and broadcast it around the world. The Connemara Celtic Band played in the main lobby of Building 1, and the Navy's Country Current and Sea Chanters entertained guests in the tent and Building 56.

The submarine community also got in the act; on the occasion of their 100th anniversary the sub centennial jack was unfurled shortly after midnight, and the historic *Turtle* and *Hunley* (all 75 feet of it) submarine models were on display. The Secretary of the Navy, the Secretary of the Air Force and numerous VIP guests attended, and approximately 1000 others gathered for the time ball drop and the spectacular fireworks, shot off from the north lawn. After it was all over Secretary Danzig was presented a plaque, and personally re-enlisted QMC Barry Wass. All-in-all, a night to remember!

The entire event, as well as the "When is the Millennium?" question, brought much national and local media coverage to USNO. It was an excellent example of how history can be combined with mission goals to increase the USNO profile among the public and the DoD.

Primary thanks go the members of the USNO Millennium Committee, without whom none of this would have happened: Geoff Chester, Alan Fey, Mihran Miranian, Susan Stewart, Annette Hammond, Ted Rafferty, John Pohlmann, Gail Witcher, with special help near the end from Sheila Faulkner. Nor could it have happened without the work of FM-NDW, the police, and many volunteer employees, and participation from local Astronomy Clubs.

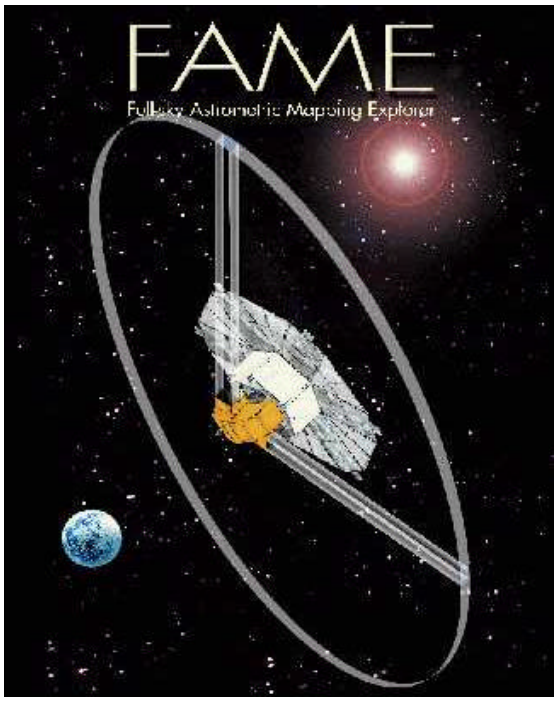
More information on the millennium program and the round-the-world ball drop is available at the USNO millennium web site, http://www.usno.navy.mil/millennium/.

FAME Selected to Fly in 2004!

The National Aeronautics and Space Administration (NASA) has selected the USNO's Full-sky Astrometric Mapping Explorer (FAME) satellite to be funded for launch in 2004. FAME is an optical space telescope designed to determine the positions, distances, motions, brightness, and colors of stars in our galactic neighborhood. It will observe and determine the positions of stars brighter than 15th magnitude, which is about 40 million stars.

"FAME will provide a rich and unprecedented database for a wide range of studies in stellar astrophysics," says Dr. P. Kenneth Seidelmann, the Director of Astrometry at the Naval Observatory and the Chairman of the FAME science team. "It will be the most accurate astrometric catalog in history."

Astrometry, the science of determining positions of stars, is the oldest branch of astronomy. Astrometric measurements not only determine the positions of stars on the sky, but also the distances to stars by measuring their parallaxes. The parallax is the apparent change in a star's position due to the Earth's revolution around the Sun over the course of a year. "Astrometric observations are fundamental measurements that are the foundation of almost all of astrophysics," said Sean Urban, a USNO astronomer.



FAME will be able to detect giant planets larger than twice the mass of Jupiter orbiting neighboring stars. By measuring the positions of stars over time, FAME will be able to detect the "wobbling" of stars due to companion objects such as other stars, brown dwarfs, and giant planets. By directly measuring the distances to a special class of stars called Cepheids, FAME will improve our knowledge of distances to galaxies and our understanding of the size of the Universe. Cepheids are currently used for this purpose, however distances to the Cepheids themselves are not known precisely; FAME will solve this problem. FAME will also be able to determine the amount of dark matter in the disk of our Milky Way galaxy by observing its gravitational influence on stellar motions.

"FAME will give us the ability to study the variability of a large number of Sun-like stars, enabling us to put the Sun's activity level in the context of other similar stars," says Dr. Scott Horner of Lockheed Martin Corporation, "This will indicate whether solar variability may change on long time scales, with possible implications for climate change on Earth."

FAME's innovative design uses a solar sail to utilize the pressure from sunlight to change the orientation of the spacecraft in order to scan the entire sky. The FAME telescope looks in two directions at once to achieve its high accuracy. It rotates with a period of 40 minutes.

The FAME team is lead by Dr. Kenneth J. Johnston, the Scientific Director of the U.S. Naval Observatory in Washington, DC. The FAME project is a collaborative effort of the U.S. Naval Observatory, the Naval Research Laboratory (Washington, DC), Lockheed Martin Missiles and Space Advanced Technology Center (Palo Alto, CA), and the Smithsonian Astrophysical Observatory (Cambridge, MA). The FAME project has a total mission cost to NASA of $162 million, with additional support provided by the Navy to extend the duration of the operation of the FAME satellite.

The Explorer program, run by NASA's Office of Space Science and managed by NASA's Goddard Space Flight Center (Greenbelt, MD), provides frequent opportunities for scientific investigations from space at relatively low cost. FAME is a medium-class Explorer (MIDEX), which are the largest of the Explorer program missions. Teams of astronomers, space physicists, and engineers compete in a two-phase process to receive funding from NASA. In the first phase, 5 of the 35 proposals submitted were selected based on their scientific merit. After more detailed concept studies were completed on these five missions - evaluating each mission's cost, management, technical plans, small business involvement, and educational outreach - NASA selected two of the five missions to receive funding for construction and launch.

The data from FAME will fulfill many needs of DoD, other government agencies, and the public at large for accurate astrometric data for the next two decades. The accurate star positions from FAME will enable autonomous space navigation systems to determine the positions of future satellites with accuracies better than 1 meter. Precise timing information and astrometry (star positions) are the foundation of navigation.

More information on FAME can be found at the FAME web site.

Tycho-2 Catalogue Released

Sean E. Urban, Astrometry Department

The Tycho-2 Catalogue was released to the public February 8, 2000. The Tycho-2 project was an international collaboration between the Copenhagen University Observatory (CUO), United States Naval Observatory, Astronomisches Rechen-Institut, and European Southern Observatory. The CUO group were responsible for re-processing the original photon counts from the Tycho experiment flown on the Hipparcos Satellite. The USNO group, consisting of Sean Urban, Gary Wycoff, and Tom Corbin, were responsible for producing the proper motions for the stars.

This catalogue gives positions, proper motions, and photometry for 2.5 million stars across the entire sky, with a density ranging from 25 to 150 stars per square degree. The catalogue is about 99% complete for stars brighter than V=11.0 and about 90% complete for V=11.5. The numbers of stars decreases rapidly for those fainter than V=12.0 Tycho-2 supersedes the

ACT catalogue, the TRC catalogue, and the Tycho-1 catalogue in both size and accuracy of the data.

The astrometric and photometric data are magnitude dependent; in general, the brighter stars are more accurate than the fainter ones. Photometric accuracies range from 0.02 magnitudes for the brightest stars to about 0.30 magnitudes for the faintest. Positional accuracies range from 10 mas to about 120 mas from brightest to faintest. Proper motion accuracies are more consistent, from less than 1 mas/year for the brightest stars to about 3.5 mas/year for the faintest.

In addition to an increase of 1.5 million more stars over the ACT, the proper motions should be more systematically consistent with that of the Hipparcos catalogue due to a re-reduction of some 145 individual catalogues using the Hipparcos data directly (The Hipparcos Catalogue was not available during most of the ACT compilation). Individual stars should also have better determined proper motions due to the inclusion of these 145 catalogues in the proper motions, not just the Astrographic Catalogue and Tycho positions as was done in producing the ACT.

Several USNO projects will be affected by the availability of the Tycho-2 catalogue. It will be utilized to reduce the 2MASS data, the Sloan Digital Sky Survey and the UCAC fields. There are currently scientific papers submitted by the members of the Tycho-2 team that have utilized its proper motions to identify a new, young moving group of stars and to put physical constraints on the Hyades open star cluster.

It is anticipated that Tycho-2 will become the standard reference catalogue when one needs additional density beyond that provided by Hipparcos. It should remain as such until another USNO product, the UCAC catalogue, is completed around the year 2004.

Sean Urban is the USNO point of contact on this project. He has a small supply of CD-ROMs for those needing them. The data can also be downloaded via the WWW. The homepage with descriptions and links can be reached under http://ad.usno.navy.mil.

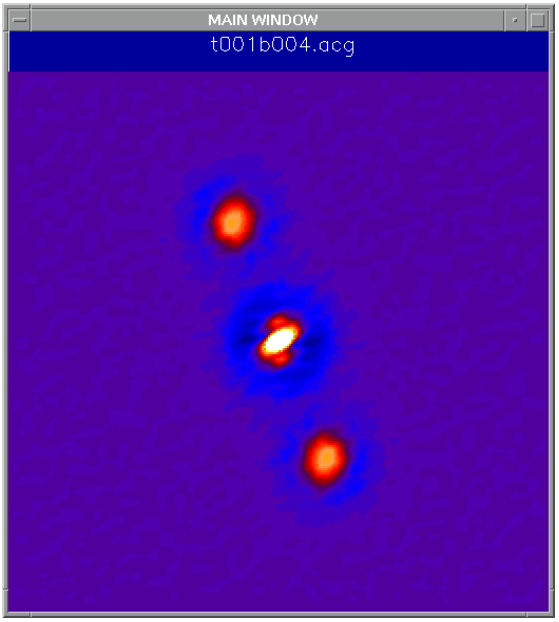
USNO Novelized!

Steven J. Dick, History and Public Affairs

In January well-known author Thomas Mallon published his novel *Two Moons.* The novel takes place in 1877, and centers around the USNO at its Foggy Bottom site at the time Asaph Hall discovered the two moons of Mars. Try it! The opening scene is the time ball dropping!

New Technique Tested for Measurements of Jupiter's Satellites

George Kaplan, Astronomical Applications Department



Computer-processed image of Io and Europa, after many snapshots have been measured and averaged. The bright spots are not Io and Europa individually, but mathematical peaks in what is called the autocorrelation function of the two images. If there is a small, bright center in each spot, good measurements will result.

A new technique for measuring the precise positions of the four brightest satellites of Jupiter is being evaluated at USNO. The technique, called *speckle interferometry*, has been applied quite successfully by the USNO Astrometry Department for measuring the

relative positions of the stars in binary systems. A very active program of observations for that purpose is being carried out on the 26-inch telescope. A special camera attached to the telescope takes a series of rapid electronic snapshots of a close pair of stars and sends them to a computer for processing. The technique is based on the principle that in these short-exposure, high-magnification snapshots, the image of each star is distorted by the Earth's atmosphere into a splotch of dots, called speckles. The pattern of speckles is quite similar for two stars if they are close enough together to appear in the same snapshot. For each snapshot, the computer software uses a sophisticated mathematical trick that, in essence, shifts the image of one star until it exactly overlaps that of the other star. The amount of the shift necessary then tells us the relative position of the two stars very accurately.

Beginning a little over a year ago, we started using the same equipment and software on the four bright satellites of Jupiter, on occasions when any two of them are close enough together on the sky to form a pair that fit within the camera's field of view. Essentially, we treat the pair of satellites like a binary star (a temporary one) for measurement purposes. Depending on where the satellites are in their orbits and how close they come to each other, we can observe the pair for 20 minutes to several hours. The people involved in this project so far are Brian Mason, Bill Hartkopf, Geoff Douglass, Ted Rafferty, and Ellis Holdenried, and Dan Pascu of the Astrometry Department (AD) and George Kaplan of the Astronomical Applications Department (AA). Wendy Hultquist (AA) has just joined the team to help with the calibration of the data. There has been very little previous work in using speckle interferometry for astrometry of bodies in the solar system. As we have learned, applying a technique designed for stars to a completely different kind of astronomical object presents some interesting challenges.

One is simply getting enough observations. Binary stars can be observed almost anytime it's clear. But our technique works for the satellites of Jupiter only when two of them happen to pass quite close together in the sky (in angular units, within a few arcseconds). Because of what are called resonances among the orbits of these satellites, observable events happen in series that span about a month's time. These event series are separated by about six months. So, most of the time, there is nothing that can be observed! And, of course, some of the events occur when Jupiter is below our horizon, in the daytime, or in cloudy weather.

Geoff Douglass (AD, now retired) at the computer connected to the speckle interferometry camera on the 26-inch telescope. Highly magnified images of Jupiter's satellites Io and Europa can be seen in the monitor at the right.

Another difference is that stars are so far away that, aside from the distortions caused by our own atmosphere, they are essentially points of light. But the satellites of Jupiter are close enough that they have a measurable width (up to 1.7 arcseconds across) and look like tiny disks. Thus, at the beginning of this project, we were not sure that the software used to process pairs of star images would work with larger images. But this turned out not to be a problem. Our first observation, of a close pairing of Io and Europa in November of 1998, gave very good measurements.

More challenging is the issue of timing. The hardware is not designed for accurate timing of observations, because most binary stars have orbital periods of decades or even centuries. But the motion of Jupiter's satellites is fast enough that even a second's error can be significant for the precision (about 10 milliarcseconds) we are trying to achieve. We are still working to accurately "tag" the observations with accurate time. Related to this is the fact that the satellites' rapid relative motion limits the number of snapshots that we can average together for a measurement — otherwise there will be blurring. So in certain circumstances the measurement precision will be degraded by electronic noise that we can't totally remove from the observations by averaging. It turns out that there is quite a range in the speed of the satellites' apparent relative motion,

so that the timing problems affect each satellite pairing event differently.

So far we have observed about a half-dozen satellite events. Analysis of these observations is still in progress. A poster paper on our preliminary results was presented at last year's meeting of the Division on Dynamical Astronomy of the American Astronomical Society. The number of satellite events we can observe increased significantly last month when the field of view of the speckle interferometry camera was effectively doubled. The number of events will also increase dramatically in the next few years as Jupiter's slow orbital motion causes the tilt of the satellites' orbital planes, as seen from Earth, to decrease. This technique may also work with some of Saturn's satellites during those years that we see the rings edge-on.

Although this is very much a part-time project for all of us, the effort has been quite rewarding. There is still plenty of work left to do to fully assess the usefulness of the technique.

Security Notes

USNO POLICE EMERGENCY NUMBERS

34th Street Gate (24 Hours): 762-1468

Shift Lieutenant: 762-0336

Shift Sergeant: 762-0338

Local Emergency Number: Dial 99 + 911.

When calling the local emergency number please notify the USNO police in order to escort the emergency personnel and vehicles to the scene.

GATES (Hours of Operation):

34th Street Gate: Open 24 Hours/7 Days Per Week

South Gate: Open Monday through Friday, 0545 - 1830

Wisconsin Gate: Closed until further notice

Davis Street Gate: Closed

Gilliss Avenue Gate: Opened as Directed, otherwise closed

Wisconsin Turnstile: 24 Hours Daily (Must have USNO Swipe Card to re-enter)

USNO In The News

Geoff Chester, Public Affairs

The latter half of 1999 proved to be a busy time for USNO as the approach of Y2K drew near. The Public Affairs Office was bombarded with media inquiries about the event, and from October on it seemed that hardly a week went by without at least one film crew on the base. Print reporters also made extensive use of the Observatory's expertise, with feature articles appearing in such diverse publications as the Navy's "All Hands" magazine to the syndicated "Mini-Page".

In the midst of all this, the media also produced extensive coverage of the Leonid meteor shower and the Mars Polar Lander, resulting in USNO's name appearing on dozens of local news shows as well as the national "NBC Nightly News" and worldwide via CNN and MSNBC cable networks.

ABSTRACTS OF RECENT PAPERS:

VLBA OBSERVATIONS OF RADIO REFERENCE FRAME SOURCES. III. ASTROMETRIC SUITABILITY OF AN ADDITIONAL 225 SOURCES

Alan L. Fey and Patrick Charlot

Submitted for publication in the *Astrophysical Journal Supplement Series*

ABSTRACT:

We present simultaneous dual-frequency Very Long Baseline Array 2~GHz and 8~GHz observations of 225 of the 560 extragalactic sources for which positions were reported by Johnston et al. (1995) and

which are now part of the International Celestial Reference Frame. These observations represent the third and final in a series of observations intended to obtain single-epoch images of the entire set of sources presented by Johnston et al. and, together with previously reported observations, bring the total number of sources observed to 389. As with previous papers in this series, we use these data to quantify the magnitude of the expected effect of intrinsic source structure on astrometric bandwidth synthesis Very Long Baseline Interferometry observations and to calculate a source "structure index" for the observed sources. The structure index can be used as an estimate of the astrometric quality of the sources. Based on this indicator, correlations between the observed radio structure and the astrometric position accuracy and stability of the sources have been found. These correlations indicate that the more extended sources have larger position uncertainties and are less positionally stable than the more compact sources.

THE EXTREME SCATTERING EVENT TOWARD 1741-038: VLBI IMAGES

T. Joseph W. Lazio, A. L. Fey, Brian Dennison, F. Mantovani, J. H. Simonetti, Antonio Alberdi, A. R. Foley, R. Fiedler, M. A. Garrett, Hisashi Hirabayashi, D. L. Jauncey, K. J. Johnston, Jon Marcaide, Victor Migenes, G. D. Nicolson, and Tiziana Venturi

Accepted for publication in the *Astrophysical Journal*

ABSTRACT:

We report multi-epoch VLBI observations of the source 1741-038 (OT-068) as it underwent an extreme scattering event. Observations at four epochs were obtained, and images were produced at three of these. One of these three epochs was when the source was near the minimum flux density of the ESE, the other two were as the flux density of the source was returning to its nominal value. The fourth epoch was at the maximum flux density during the egress from the ESE, but the VLBI observations had too few stations to produce an image.

During the event the source consisted of a dominant, compact component, essentially identical to the structure seen outside the event. However, the source's diameter increased slightly at 13 cm, from near 0.6 mas outside of the ESE to near 1 mas during the ESE. An increase in the source's diameter is inconsistent with a simple refractive model in which a smooth refractive lens drifted across the line of sight to 1741-038. We also see no evidence for ESE-induced substructure within the source or the formation of multiple images, as would occur in a strongly refractive lens. However, a model in which the decrease in flux density during the ESE occurs solely because of stochastic broadening within the lens requires a larger broadening diameter during the event than is observed. Thus, the ESE toward 1741-038 involved both stochastic broadening and refractive defocusing within the lens. If the structure responsible for the ESE has a size of order 1 AU, the level of scattering within an ESE lens may be a factor of 107 larger than that in the ambient medium. A filamentary structure could reduce the difference between the strength of scattering in the lens and ambient medium, but there is no evidence for a refractively-induced elongation of the source. We conclude that, if ESEs arise from filamentary structures, they occur when the filamentary structures are seen lengthwise.

We are able to predict the amount of pulse broadening that would result from a comparable lens passing in front of a pulsar. The pulse broadening would be no more than 1.1 us, consistent with the lack of pulse broadening detected during ESEs toward the pulsars PSR B1937+21 and PSR J1643-1224.

The line of sight toward 1741-038 is consistent with a turbulent origin for the structures responsible for ESEs. The source 1741-038 lies near the radio Loop I and is seen through a local minimum in 100u emission.

ANISOTROPIC INTERSTELLAR SCATTERING TOWARDS THE CYGNUS REGION

K. M. Desai and A. L. Fey

Submitted for publication in the *Astrophysical Journal*

ABSTRACT:

We report on multi-frequency VLBA observations of

interstellar scattering (ISS) towards four extra-galactic sources seen through the Cygnus region, 2005+403, 2008+332, 2021+317, and 2048+312. We are able to successfully determine scattering disk parameters at frequencies up to 5.0 GHz for 2005+403 and 2008+332 and up to 2.3 GHz for 2048+312. We were unable to reliably determine scattering disk parameters for 2021+317 at frequencies from 8.5 GHz down to 1.67 GHz because of its complex intrinsic source structure. The scattering disks are elliptical with axial ratios of about 1.33:1 with little measurable variation between these sources. We interpret our measurements as due to the effects of anisotropic interstellar turbulence. The ellipticity parameters, axial ratio and position angle, for those sources for which we have data at multiple frequencies appear to be frequency-independent making refractive distortions of isotropic turbulence an unlikely explanation. Our estimates of ß, the power-law index of the power spectrum of electron density fluctuations, based upon direct model fits to the data on a source-by-source and frequency-by-frequency basis, are consistent with ß=4 for most of the data but are strongly affected by our estimate of the intrinsic structure of the sources. Two of these sources, 2005+403 and 2021+317, exhibit significant intrinsic source structure at frequencies as low as 1.67 GHz while the other two, 2008+332 and 2048+312, lack discernible source structure at frequencies lower then 2.3 GHz. The frequency scalings of the scattered angular sizes are also consistent with ß=4. We discuss the implications of our measurements for the inner and outer scales of the turbulence.

VSOP AND GROUND-BASED VLBI IMAGING OF THE TEV BLAZAR MARKARIAN 421 AT MULTIPLE EPOCHS

B. G. Piner, S. C. Unwin, A. E. Wehrle, P. G. Edwards, A. L. Fey, and K. A. Kingham

Accepted for publication in the *Astrophysical Journal*

ABSTRACT:

We present thirty VLBI images of the TeV blazar Markarian 421 (1101+384) at fifteen epochs spanning the time range from 1994 to 1997, and at six different frequencies from 2.3 to 43 GHz. The imaged observations include a high-resolution 5 GHz VLBI Space Observatory Program (VSOP) observation with the HALCA satellite from 1997 November 14; full-track VLBA observations at 5, 15, 22, and 43 GHz from 1994 April, 1996 November, and 1997 May; six epochs of VLBA snapshot observations at 2, 8, and 15 GHz done as part of a study of the Radio Reference Frame; and five geodetic VLBI observations at 2 and 8 GHz from the archive of the Washington VLBI Correlator Facility located at the U.S. Naval Observatory. The dense time coverage of the images allows us to unambiguously track components in the parsec-scale jet over the observed time range. We measure the speeds of the three inner jet components to be 0.19+/-0.27, 0.30+/-0.07, and -0.07+/-0.07 c (Ho = 65 km/s/Mpc, qo = 0.1). These speeds disagree with a previously published superluminal speed based on three epochs of data by Zhang & Baath. Possible interpretations of these subluminal speeds in terms of the high Doppler factor demanded by the TeV variability of this source are discussed.

NAVIGATION AND PRECISE TIME

Dennis D. McCarthy
U. S. Naval Observatory

To be published in the *Proceedings of the NAO Sesquicentennial Symposium*

Precise time has traditionally been associated with navigation and this association continues to grow today. From celestial navigation to the Global Positioning System (GPS), precise time is an essential component in obtaining a precise location. The accuracy of navigation is directly related to our ability to keep precise time. As we go forward, the navigational requirement will continue to drive attempts to improve timing precision and to make precise time available to the user.

[Note: Printed copies of the ***Proceedings of the NAO Sesquicentennial Symposium*** should be available by mid-March.]

USNO
H*A*P*P*E*N*I*N*G*S
Y2K at USNO

As the Master Clock Struck Midnight...

SECNAV Richard Danzig, assisted by USNO Superintendent CAPT Dennis Larsen, pulled the handle...

That triggered the Time Ball...

And the Time Cannon...

....And

The

Fireworks!

Photographs courtesy of NDW PAO

The U.S. Naval Observatory *Star*
U.S. Naval Observatory, Washington, D.C.

Superintendent
Captain Ben Jaramillo

Deputy Superintendent
Commander Mark Gunzelman

Scientific Director
Dr. Ken Johnston

Editor
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